
CHAPTER 15 ENERGY IN HAWAII AND FUTURE TECHNOLOGY

15.1 Overview

This report has focused on ways to improve Hawaii's energy efficiency, reduce Hawaii's dependence on imported fossil fuels, increase the use of indigenous renewable energy resources, and to reduce greenhouse gas emissions.

DBEDT believes that new technology is needed to make major changes in Hawaii's energy system, to reduce energy costs, and reduce fossil fuel use and the resultant greenhouse gas emissions. In the model runs and analysis, existing technologies were considered in developing and addressing options. In the energy sector in particular, the estimates indicated that it would be very difficult to reach the Kyoto Protocol goal of 7% below 1990 levels of greenhouse gas emissions by the years 2008–2010 using existing technologies.

This chapter discusses several research and development efforts currently underway in Hawaii that may allow use of indigenous energy resources or more efficient fuels, such as hydrogen. These technologies could also contribute to reducing greenhouse gas emissions. The chapter also examines a number of other technologies under development that are expected to provide energy and transportation more efficiently and with reduced greenhouse gas emissions.

15.2 Technology, Economic Growth, and the Environment

In a draft paper prepared for DBEDT, entitled *Economic Opportunities in Energy and Resource Efficiency*, Lawrence J. Hill of the U.S. Department of Energy's Oak Ridge National Laboratory summarized the connection between technology, economic growth, and the environment. He wrote:

Changes in technology are revolutionizing where and how products are produced. Technological change has already led to the introduction of information-related technologies and the innovation pipeline has not nearly been exhausted. . . .

There are two consequences of these innovations. First, these new technologies require electricity as their fuel. The global demand for electricity, then, will be larger than it would have been without the technologies. The new information technologies will also make firms more efficient, promising higher growth rates for many economies and, consequently, an increased demand for electricity. Second, new information technologies afford business firms the opportunity to become global, allowing them to move their operations from one country to another based on local economic and political considerations. An important consideration – and one that policy makers are increasingly aware of – is the cost of doing business in a community. High resource prices do not attract these global firms.

Technological innovation in the electric industry also portends significant changes. For example, dramatic improvements in the efficiency of gas turbine power plants have reduced the cost of producing electricity from these plants and have reduced the minimum size of the plants needed to obtain the cost reduction. These improvements have led national and state policy makers to legislate changes in the structure of the electric industry.

In this new structure, the electric industry will be broken apart. . . . The traditional electric ‘monopoly’ will no longer be the sole provider to customers. . . .

These technology-driven changes are intensifying concerns about global climate change resulting from greenhouse gas emissions from electric power plants and increased industrial production fueled by technological innovation. . . .

Improving energy efficiency is one tool that policy makers can use to address the global climate change problem. Improving energy efficiency is an important policy tool in this regard because it also results in important income and employment benefits for the local economy. (Hill 1999, 6-7)

In addition, use of indigenous, renewable energy keeps money in the local economy and provides a greater multiplier effect than purchases of imported fuels. To the extent that technology can provide for energy efficiency, greater use of indigenous energy, or both, Hawaii’s people, economy, and environment will all benefit.

15.3 Hawaii Research and Development Projects

There are a number of current and recent research and development projects in Hawaii that offer potential contributions to Hawaii’s energy system and that may help reduce the production of greenhouse gases and mitigate climate change.

15.3.1 *Hydrogen: Fuel of the Future*

Hydrogen has been called the fuel of the future. It may be the ultimate energy carrier – a versatile, transportable fuel that can be converted easily and efficiently to other forms of energy without producing harmful emissions. Hydrogen can be used as a fuel for transportation, electricity generation, cooking, and heating. It can be produced from renewable resources, such as electrolysis of water into hydrogen and oxygen using solar energy or wind energy, or by direct conversion of biomass into hydrogen and other gases (HNEI 1998).

In the past, the cost of production, difficulties in storage, and lack of infrastructure have been obstacles to the everyday use of hydrogen. The U.S. Department of Energy (USDOE) Center for Excellence for Hydrogen Research and Education at the University of Hawaii’s Hawaii Natural Energy Institute (HNEI) is conducting research to address the cost and storage issues. Work is underway in the area of

photoelectrochemistry, biomass gasification of hydrogen, and hydrogen storage technologies (HNEI 1998).

15.3.1.1 Photoelectrochemistry

Research is being conducted at HNEI on ways to electrolyze water into hydrogen and oxygen using only sunlight for energy. Analyses indicate that photoelectrochemical reactors based on multijunction amorphous silicon solar cell technologies can potentially achieve highly efficient production of hydrogen at reasonable cost. Using high-efficiency, triple junction amorphous silicon solar cells provided by Solarex Thin Film Division and HNEI's own thin-film catalytic coatings, researchers have demonstrated conversion efficiencies greater than 7.5%. The technology has operating lifetimes in excess of 7,000 hours. HNEI research is now focused on improving protective coatings. In collaboration with the National Renewable Energy Laboratory, HNEI is also working to optimize the engineering design of these photoelectrochemistry reactors (HNEI 1998).

15.3.1.2 Biomass Gasification to Create Hydrogen

Researchers at HNEI's Renewable Resources Research Laboratory are optimizing a new catalytic process that causes biomass to react with "supercritical water" (water at high temperatures and pressures) to produce hydrogen, CO₂, and some CH₄. The process is similar to techniques currently used for commercial production of hydrogen using reaction of natural gas (CH₄) with water. The advantage of HNEI's process is that it can use renewable biomass (such as wood sawdust, water hyacinth, banana stems, or sewage sludge) and supercritical water as reactants. Unlike all other biomass gasification processes, the HNEI process produces no tars or char, only a hydrogen-rich gas. A patent is pending on the process and researchers recently issued a second patent disclosure. With support from the U.S. Department of Energy, General Atomics Corporation is now preparing a business plan to commercialize the HNEI work (HNEI 1998).

15.3.1.3 Hydrogen Storage Technology

Hydrogen storage has long been a problem. Hydrogen is normally stored as a gas in high-pressure tanks, or as a liquid at cryogenic temperatures. Hydrogen can also be stored as a solid by reacting it with a variety of metals. These materials, known as metal hydrides, provide safe, low-pressure storage; however, the process has so far proven able to store hydrogen only in amounts too small to be practical. In other cases, the hydrogen has been found to form too strong a bond with the metal hydride, requiring large energy inputs for its release (HNEI 1998).

Over the ten years from 1986 to 1996, HNEI's research has focused on developing "non-classical" polyhydrides – transition metal complexes – as storage media. Experiments showed that this new class of material could store and discharge hydrogen with lower energy inputs than conventional hydrides (HNEI 1998).

Recently, HNEI researchers discovered that these same metal complexes can catalyze the dehydrogenation of cyclic aromatic hydrocarbons at low temperatures, a step that had long been a barrier to using such hydrocarbons as a

storage media. Research has been redirected to concentrate on the development of metal complex catalytic systems for reversible hydrogenation of unsaturated hydrocarbons. Within the past year, new and significantly improved catalysts have been developed. HNEI also initiated studies to characterize the kinetics and thermodynamics of the reaction system. Future work will include improvement of the fundamental properties of catalysts and construction of a membrane reactor to demonstrate reversible operation of the hydrocarbon storage system (HNEI 1998).

15.3.2 *New Technology for Charcoal Production*

Charcoal has been made in virtually the same way for 6,000 years. The process is long, causes severe air pollution, and has low yields. An innovation by HNEI researcher Dr. Michael J. Antal, Jr., at the University of Hawaii, offers the potential to greatly reduce production time – to an hour or less – while reducing smoke and other pollution and doubling or tripling yields. This technique could help slow deforestation and reduce pollution (and greenhouse gas emissions) in the many developing nations that use large amounts of charcoal. The process, which recently received a U.S. patent, can use a variety of feedstocks, including moist wood logs, wood chips, coconut shells, corn cobs, macadamia nut shells, and other commonly available biomass and agricultural byproducts. The greater efficiency of this method could save thousands of acres of forests from harvesting and reduce air pollution by shortening production times and improving yields.

15.3.3 *Open-Cycle Ocean Thermal Energy Conversion*

The technology for generating electricity from different ocean temperatures is known as ocean-thermal energy conversion, or OTEC. OTEC makes use of the difference in temperature between the warm surface water of the ocean and the cold water at depths below 2,000 feet to generate electricity. As long as a sufficient temperature difference (about 40 degrees Fahrenheit) exists between the warm upper layer of water and the cold deep water, net power can be generated.

Almost all of major U.S. OTEC experiments in recent years have taken place in Hawaii. The Natural Energy Laboratory of Hawaii Authority (NELHA), on the Big Island, is recognized as the world's foremost laboratory and test facility for OTEC and OTEC-related research. The State of Hawaii funded the facility, with significant USDOE participation. The Pacific International Center for High Technology Research (PICHTER), in Honolulu, designed, constructed, and operated a 210-kilowatt open-cycle OTEC plant. When it was operational, the plant set the world record for OTEC power production, at 255 kilowatts gross. Testing ended in 1997.

OTEC continues to offer a way to generate electricity without producing greenhouse gas-. Additional research, component cost reduction, and funding of a utility-scale plant are needed to create a viable commercial technology.

15.3.4 *International CO₂ Ocean Sequestration Field Experiment*

During the Third Conference of the Parties of the Framework Convention on Climate Change, at Kyoto in December 1997, agencies of the governments of the United States, Japan, and Norway signed a major international research agreement to develop technologies to sequester CO₂ removed during fossil fuel combustion to keep it from entering the atmosphere. Under the agreement, researchers from the three nations will test the feasibility of deep-ocean sequestration of CO₂ via discharge from submerged pipelines.

The objective of the experiment is to identify safe and practical means of reducing CO₂ emissions while ensuring a stable and inexpensive energy supply. The first phase of the experiment will release a modest amount of CO₂ at depths of more than 3,000 feet during the course of a month. Researchers will gather data on the dissolution and dilution of the CO₂ to assess any impacts on the deep-ocean environment and to develop models of the discharge that can be used to predict and quantify changes in sea water chemistry. PCHTR is the general contractor, and the experiment will take place in the ocean research corridor offshore of the Natural Energy Laboratory of Hawaii Authority at Kailua-Kona, Hawaii.

It should be noted that ocean sequestration is potentially well suited for fossil-fueled power stations in Hawaii. As noted in Chapter 7, Hawaii's power producers do not enjoy the option of switching to lower cost and lower carbon content fuels such as natural gas as Mainland utilities can. CO₂ removal from stack gases and sequestration in the deep ocean could be added to other CO₂ reduction options such as improved heat rate, energy efficiency programs, and use of renewable energy resources.

Hawaii's power stations probably have the best access to the deep ocean in the U.S. (Masutani 1998). The USDOE, however, estimates that about 30% of U.S. power plants would have access to deep-water sequestration (USDOE 1997b). A pilot facility planned by the three nation consortium for development in the 2005–2010 time frame, could well be sited in Hawaii, possibly next to the Hawaiian Electric Company's Kahe station on Oahu (Masutani 1998).

Hawaii researchers have previously proposed and published papers on a process to reduce CO₂ emissions from power plants by “precombustion reforming” of fossil fuel and deep-ocean discharge of the CO₂ separated from the fuel. The process involves reforming a hydrocarbon fuel into a mixture of hydrogen and CO₂ before combustion takes place. The gases are separated and the hydrogen is used for power generation while the liquefied CO₂ is discharged into the deep ocean. Based upon their analysis of a 500 MW methane-fueled power plant, Nihous et al. (1994) reported that it appeared that the system would incur moderate power and cost penalties. In the future, such measures may be among those necessary to reduce CO₂ emissions and their impact on global climate.

15.4 Future Technology

15.4.1 *The Need for New Technologies*

Hawaii, and the rest of the world, will need new technologies to effect significant improvements in energy efficiency, to increase use of renewable energy, and to achieve the reductions in greenhouse gas emissions necessary to reduce the consequences of global warming and other, related, changes in the global climate. In the context of HES 2000, it is stressed that improvements in energy efficiency and use of renewable energy also offer economic and other environmental benefits.

The U.S. Secretary of Energy recently asked the Directors of the Department of Energy's national laboratories to identify technologies that could be used to meet this challenge nationally. The study was summarized in *Technology Opportunities to Reduce U.S. Greenhouse Gas Emissions* (NLD 1997), published in October 1997. As the National Laboratory Directors stated, "Advances in science and technology are necessary to reduce greenhouse gas emissions from the United States while sustaining economic growth and providing collateral benefits to the nation" (NLD 1997, xiii).

15.4.2 *The Outlook for Technological Solutions*

The National Laboratories Directors pointed out that solutions available early are have greater impact in reducing emissions than those available later. They believe that by 2030 a vigorous research, development, and demonstration program could result in a "wide array of cost-effective technologies that together could reduce the nation's carbon emissions by 400–800 million metric tons of carbon per year. This decrease represents a significant portion of the carbon emission reductions that may be targeted by the U.S. for 2030" (xiv).

Looking ahead over the next thirty years, each decade was characterized by a distinct range of potential technologies for reducing greenhouse gas emissions. The technological pathways identified were energy efficiency, clean energy, and carbon sequestration.

In the first decade (2000–2010), advances in energy efficiency would reduce the energy intensity of the U.S. economy. The use of clean-energy technologies would continue to grow, and carbon sequestration technologies could begin to emerge.

In the second decade (2011–2020), continued improvements in energy efficiency, and research-based advances in clean-energy technologies would significantly reduce the amount of carbon emitted per unit of energy used. A wide variety of improved renewable, nuclear, and fossil energy technologies could be introduced.

By 2025, during the third decade (2021–2030), the impacts of reductions through clean energy technology could begin to exceed the impact of increased energy efficiency. Success in the area of carbon sequestration is seen to be essential for the U.S. to continue its extensive use of fossil fuels without harming the global environment (xiv).

The following table, 15.1, is based upon the National Laboratory Director's study. It presents an illustrative time-line of anticipated technology products for the energy sector, 2000–2030 (5-10–5-11).

Table 15.1 Illustrative Time-Line of Anticipated Technology Products, 2000-2030		
2000	2005	2010
Energy Efficiency	Energy Efficiency	Energy Efficiency
1 kWh/day refrigerator	Fuel cells providing combined heat and light for commercial buildings	Widespread use of hybrid lighting, combining light concentrators, efficient artificial sources, and fiber-optic distribution systems
80% efficient advanced turbine system for industrial cogeneration	R-10+ windows and electrochromic windows	Real-time monitoring of water and nutrients in agricultural systems
Advanced industrial process sensors and controls	Energy efficient catalysts for chemical synthesis	Three times greater fuel economy vehicle
Direct injection stratified charge gasoline engine	Clean Energy	Clean Energy
Advanced heavy duty diesel	Gasoline electric hybrid vehicle	Hybrid fuel cell advanced turbine system for power generation with efficiencies of 70%
	Clean diesel for light trucks and sport utility vehicles	Biofuels competing with petroleum-based transportation fuels
	Co-firing with biomass and coal	Clean coal technologies increase efficiencies to 55%
	Wind-generated electricity at 2.5 cents per kWh	Superconducting transformers and 200 HP+ industrial motors
	Superconducting cables for underground transmission	Carbon Sequestration
		Injection of carbon into aquifers

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Table 15.1 Illustrative Time-Line of Anticipated Technology Products, 2000-2030			
2015	2020	2025	2030
Clean Energy	Energy Efficiency	Energy Efficiency	Clean Energy
Widespread production of chemicals from biomass feedstocks	Phase-change building materials with storage capacity and adaptive release rates	NEW SYSTEM: Mass produced customized buildings and integrated envelope and equipment systems designed and sized for specific sites and climates	NEW SYSTEM: Broad-based biomass industry with new crops and feedstocks producing food, transportation fuels, chemicals, materials, and electricity
Hydrogen fuel cell vehicle	NEW SYSTEM: Widespread use of industrial ecology principles with linked industries and energy cascading	Travel demand reductions through real-time information systems	Utility scale photovoltaic systems
Superconducting generators for utility systems	Clean Energy	Clean Energy	NEW SYSTEM: Fission reactors with proliferation resistance, high efficiency, and lower costs
Diesel fuels from natural gas	Production of hydrogen from solar conversion of water	Advanced geothermal hot dry rock and magma energy systems	
Photovoltaics for distributed and peak shaving utility systems	NEW SYSTEM: Mature hydrogen supply infrastructure enabling multiple modes of hydrogen based transportation		NEW SYSTEM: Energyplexes that integrate fossil fuel-based production of power, fuels, and chemicals from coal, biomass, and municipal wastes with nearly zero emissions
	Simultaneous gas hydrate production and CO ₂ Sequestration		Carbon Sequestration
	Feasibility of oceanic sequestration established		Enhanced natural CO ₂ absorption

15.4.3 *National Goals for Research, Development, and Demonstration*

The National Laboratory Directors suggested the following goals for a Research, Development, and Demonstration (RD&D) program:

15.4.3.1 National Energy Efficiency RD&D Goals

- Use energy more efficiently through the development of advanced technologies (e.g., intelligent building control systems, cost-effective refrigerators that use half as much electricity as today's models, and fuel cells for heat and power in commercial buildings);
- Reduce the use of gas and oil for space and water heating through building efficiency measures (e.g., super insulation, gas-fired heat pumps that provide highly efficient space heating and cooling, and building envelopes that capture and store solar energy for later use). (Note: While Hawaii has minimal space-heating requirements, some of these measures can reduce the need for air conditioning or be used to provide cooling in large buildings. Solar water heating remains an important technology for Hawaii's residential and smaller commercial buildings.);
- Improve industrial resource recovery and use (e.g., develop an integrated gasification, combined cycle power technology, that can convert coal, biomass, and municipal wastes into power and products) and industrial processes to save energy (e.g., advanced catalysts and separations technologies);
- Increase transportation efficiency through new technologies (e.g., a hybrid electric vehicle that is three times more fuel-efficient than today's standard model) (xv).

15.4.3.2 National Clean Energy RD&D Goals

- Change the energy mix to increase use of sources with higher generating efficiencies and lower emissions, including increased use of natural gas, safer and more efficient nuclear power plants, renewable energy (e.g., solar and wind power; electricity and fuels from agricultural biomass), and hydrogen (to produce electricity through fuel cells);
- Develop "energyplexes" that would use carbon efficiently without emitting greenhouse gases for the integrated production of power, heat, fuels, and chemicals from coal, biomass, and municipal wastes;
- Distribute electricity more efficiently to reduce emissions (e.g., distributed generation using superconducting transformers, cables, and wires);

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- Switch transportation to energy sources with lower emissions (e.g., trucks that run on biodiesel fuel or ethanol from cellulosic feedstocks);
 - Remove carbon from fuels before combustion. (xv).

15.4.3.3 National Carbon Sequestration RD&D Goals

- Efficiently remove carbon dioxide from combustion emissions before they reach the atmosphere;
- Increase the rate at which oceans, forests, and soils naturally absorb atmospheric carbon dioxide;
- Develop technologies for long-term carbon storage in geological deposits, aquifers, and other reservoirs.

15.4.4.1 RECOMMENDATION: Support Deep-Ocean Carbon Sequestration Research and Possible Future Installation of a Pilot Facility in Hawaii

Suggested Lead Organizations: UH HNEI, PICHTR, NELHA, USDOE, County of Hawaii

This technology, if proven, could provide an excellent way of reducing Hawaii's near-term CO₂ emissions. If the CO₂ sequestration effort is successful, installation of a pilot facility at a power plant in Hawaii should be encouraged. Many of Hawaii's power plants could inject CO₂ from their locations relatively near the coast.

Hawaii's geography provides ready access to deep-ocean areas from coastal areas. The Natural Energy Laboratory of Hawaii Authority operates facilities that provide land-based access to deep, cold ocean waters offshore. This is highly useful for RD&D on deep-ocean carbon sequestration.

15.4.4.2 RECOMMENDATION: Conduct RD&D on Renewable Energy Technology Using Hawaii's Abundant Renewable Energy Resources

Suggested Lead Organizations: The Electric Utilities, Renewable Energy Developers, and USDOE

As noted in Chapter 7, Hawaii has significant wind and solar resources, which were identified during work on the Hawaii Energy Strategy project (see DBEDT 1995b). Hawaii has the highest national per capita use of solar water heating. In addition, volcanoes on the Big Island provide a major geothermal resource. As also noted in Chapter 7, and in the following section, Hawaii's sugar industry leads the world in efficient use of its electricity production from bagasse. Hawaii's lack of space for landfills led to construction of a municipal solid waste to energy plant on Oahu.

Land available due to the closure of sugar plantations could be used for further RD&D into biomass-to-energy systems. Although the Maui Biomass Gasifier project was canceled, Hawaii remains an excellent location for similar efforts to produce liquid fuels from biomass and municipal waste.

15.4.4.3 RECOMMENDATION: Conduct Rapid-Payback Building Efficiency RD&D in Hawaii

Suggested Lead Organizations: Electric and Gas Utilities, Energy Service Companies, Builders, Renewable Energy Developers, and USDOE

Hawaii's average statewide electricity costs are the highest in the nation. This factor enhances the attractiveness of conducting building efficiency RD&D in Hawaii. Efficiency measures will yield a rapid payback of their costs, which will help finance the RD&D. Hawaii is an excellent place to deploy new energy efficiency technologies that are being developed by USDOE. Due to the 12-month need for air conditioning in commercial buildings, Hawaii also offers an excellent location for RD&D aimed at improving the efficiency of air conditioning.

15.4.4.4 RECOMMENDATION: Conduct RD&D on Clean Energy and Transportation Energy Efficiency to Reduce Hawaii's Overdependence on Oil

Suggested Lead Organizations: Vehicle and Aircraft Manufacturers, Electric and Gas Utilities, Hawaii Transportation Companies, and USDOE

Hawaii's short driving distances make the islands an ideal location for RD&D involving widespread deployment of propane vehicles, electric vehicles, and hybrid vehicles. Hawaii's near total dependence on jet aircraft for its overseas, interstate, and interisland passenger transportation places a premium on the use of efficient aircraft. Hawaii should support RD&D efforts to improve aircraft efficiency and the development of alternative fuels for jet aircraft.

15.4.4.5 RECOMMENDATION: Conduct RD&D on Electricity System Efficiency and Clean Energy for Electricity Generation in Hawaii

Suggested Lead Organizations: Electric Utilities, Non-Utility Generators, Generator and Fuel Cell Manufacturers, USDOE

Hawaii has six relatively small, isolated electricity systems. The short transmission and distribution distances offer excellent test locations for superconductive cables, transformers, and wires. The high cost of electricity places a premium on efficiency and cogeneration (including combined heat and power systems). The isolated nature of Hawaii's systems may provide opportunities to test distributed generation systems.

Hawaii also offers the opportunity to test a variety of fossil fuels and renewable technologies in integrated systems designed to overcome the challenges posed by the intermittent nature of some renewable technologies.

Technologies developed for Hawaii's separate island systems may also have application in developing nations that lack a national or regional power grid, especially developing countries in the Asia-Pacific region. Such nations effectively have "island" systems.